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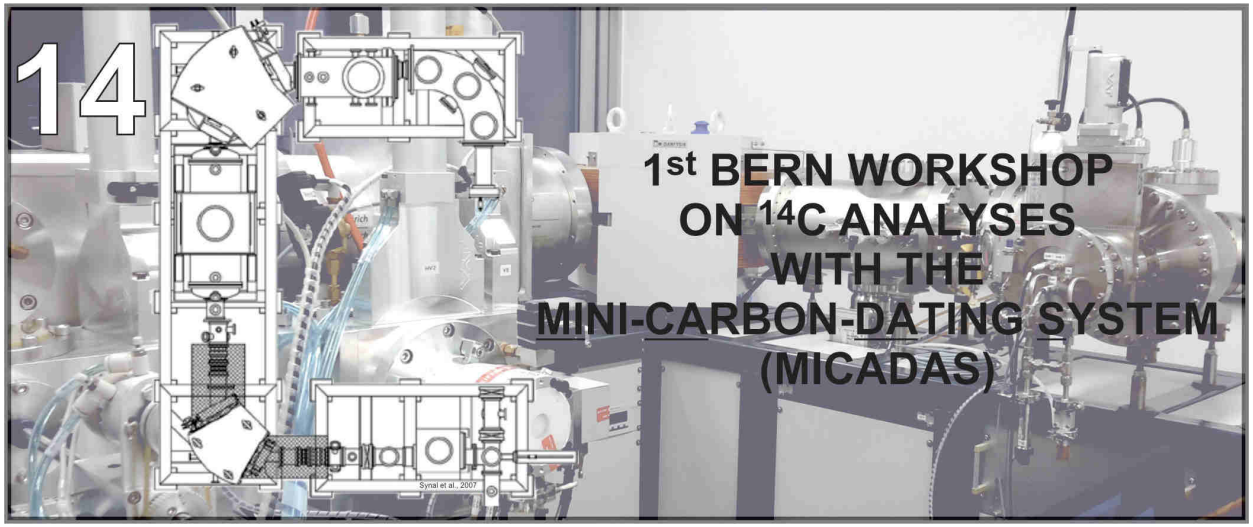

ABSTRACT BOOKLET

Technical developments and improvements of radiocarbon analyses

(Session chair: Sönke Szidat)

Keynote: Challenges in Radiocarbon analysis: Small samples and accurate dating

Lukas Wacker

Lukas Wacker [1] wacker@phys.ethz.ch
Hans-Arno Synal [1]

1. Laboratory of Ion Beam Physics, ETH Zurich, Switzerland

Accelerator Mass Spectrometry (AMS) is mostly used to determine $^{14}C/^{12}C$ ratios for radiocarbon dating, because it allows determining efficiently ^{14}C without isobaric or molecular background of relatively small samples. While for many years these measurements were performed on large tandem accelerators at energies of 3 – 6 MV, this has changed over the last 15 years. Radiocarbon measurements are now preferably carried out on compact AMS systems at energies <500 kV.

The MIni CArbon DAting Systems (MICADAS) developed at ETH Zurich works at only 200 kV and goes beyond what is generally accepted as high-precision radiocarbon measurements (<2 ‰). The main reason for this originates in the compact design, that shows more similarities to a stable isotope mass spectrometer than to an accelerator based AMS system and thus runs very stable over time. The perspectives of the MICADAS type systems are demonstrated on an example of highest-precision measurements of wood samples for the radiocarbon calibration curve.

More and more samples are analysed for radiocarbon as samples sizes are reduced from the milli-gram to the micro-gram level. For example, single compounds isolated by analytical techniques (GC, HPLC) can now be analysed. Unfortunately micro-gram samples cannot easily be converted to solid graphite. The ETH gas ion source equipped with a gas-handling interface allows for the first time precise routine measurements of micro-gram samples as CO_2 for radiocarbon dating. Examples will be given.

Invited: Developing AMS hyphenations with analytical instruments for atmospheric aerosol characterization

Gary Salazar

Gary Salazar [1, 2] gary.salazar@dcb.unibe.ch
Tabea Arnold [1]
Konstantinos Agrios [1, 2]
Sönke Szidat [1, 2]

1. University of Bern
2. Oeschger Centre for Climate Change Research

Routinely, accelerator mass spectrometry (AMS) analyzes rare isotopes which usually are in attomole to zeptomole amounts and at ultratrace proportions relative to the abundant isotope (e.g. for modern carbon $^{14}C/^{12}C \sim 10^{-12}$). Our group specializes in measuring ^{14}C for apportionment of fossil from non-fossil sources for atmospheric aerosols based on the fact that ^{14}C is completely extinct in fossil aerosol emissions. We use an aerosol analyzer that thermally desorbs molecular fractions with different volatilities from aerosol filters and transports the analytes into a combustion oven to create CO_2 peaks (FWHM~4 min). A commercial gas-handling-system traps, desorbs, dilute and injects the CO_2 into the AMS. Also, we use an elemental analyzer to separate nitrogen oxides, water and CO_2 from the sample combustion and it has also been coupled offline with the AMS. Samples sizes of 10 µg C containing 0.017-1.1 amol ^{14}C were analyzed obtaining an uncertainty of ~4%. A second type of coupling consisted on connecting online the aerosol analyzer by means of a copper reactor. By oxidation of the copper, the high O_2 flow is scrubbed away from the carrier mixture and the CO_2 is injected with a residual helium flow. This coupling bypasses the trapping step and concentrate each small sample fraction (2-10 µg C) in a peak thus the online coupling is more sensitive than the offline method. Also, the online coupling allows us to trace the ^{14}C signal in real time while changing the desorption/separation temperature of the aerosol analyzer, similar to a GC-MS system. The results show a direct evidence of a trend between fossil carbon content and volatility of the fraction components for ambient samples collected under special conditions.

Performance of MICADAS ^{14}C Instruments

Simon Fahrni

Simon Fahrni [1] fahrni@ionplus.ch

1. Ionplus AG, Dietikon, Switzerland

Laser Ablation Interface coupled to AMS for online ^{14}C analysis of carbonates

Christiane Yeman

Christiane Yeman [1] yemanc@phys.ethz.ch
C Welte [1] B Hattendorf [2] M Christl [1] J Koch [2] L Wacker [1] A H Andrews [3] R Witbaard [4] D Günther [2] H A Synal [1]

1. Laboratory of Ion Beam Physics, ETH Zurich, 8093 Zurich, Switzerland
2. Laboratory of Inorganic Chemistry, ETH Zurich, 8093 Zurich, Switzerland
3. NOAA Fisheries – Pacific Islands Fisheries Science Center, HI 96818, USA
4. NIOZ Royal Netherlands Inst. for Sea Research, 1797 SZ 't Horntje, The Netherlands

A novel method for direct and quasi continuous ^{14}C analysis of carbonates was developed, where a laser ablation (LA) interface is coupled to the gas ion source of the MICADAS (MIniCArbonDAtingSystem) accelerator mass spectrometer (AMS) at the Laboratory of Ion Beam Physics, ETH Zurich. By focusing a pulsed laser beam (ArF excimer laser 193 nm, 200 – 250 Hz) on the sample's surface, CO and CO_2 is produced, which is directly and continuously introduced into the gas ion source of the AMS and analyzed online for radiocarbon. A positioning system allows precise movement of the sample relative to the laser beam. Hence, by scanning along the growth axis of a naturally grown carbonate sample such as stalagmites, corals, shells etc. a quasi-continuous record is obtained. The high flexibility of this novel approach allows to choose the integration time and thereby measurement precision and spatial resolution during offline data reduction. Compared to standard ^{14}C sample preparation methods the LA-AMS setup has the advantages of high sample throughput, high spatial resolution, less material usage and minimal sample preparation.

Here, we present the revised setup of the LA-AMS system and apply it for the analysis of marine shells (*Arctica islandica).* In less than one hour a ^{14}C profile along the growth axis of an individual *Arctica Islandica* specimen was established revealing the complete ^{14}C bomb peak. The LA-AMS results are in agreement with the ^{14}C-AMS analysis of drilled samples that had been done previously (Witbaard et al. 1994). The new technique now can be applied in broader field studies e.g. to monitor the distribution of ^{14}C in many specimens and with large geographic coverage. Furthermore, the otoliths of red snapper *(Lutjanus campechanus)* were analyzed by LA-AMS and the ^{14}C signature recorded for the lifespan of the fish. Pre-bomb and peak ^{14}C were detected, indicating the fish lives more than 50 years.

How does ^{14}C behave in nuclear waste repositories?

Sönke Szidat

Sönke Szidat[1] soenke.szidat@dcb.unibe.ch
Gary Salazar[1]
Benjamin Z. Cvetković[2]
Dominik Kunz[2]
Erich Wieland[2]

1. Department of Chemistry and Biochemistry and Oeschger Centre for Climate Change Research, University of Bern, Bern, Switzerland
2. Paul Scherrer Institute, Laboratory for Waste Management, Villigen PSI, Switzerland

^{14}C can be used as a reaction indicator for radioactive waste (RW) deposited deep underground inside cement-based containers with activated steel parts. ^{14}N is part of the elemental composition of stainless steel (0.08-0.30%) and its interaction with thermal neutrons forms ^{14}C in reactor core components and metallic nuclear fuel components in nuclear power plants (NPP). Some time after closure of the repository, metal corrosion and presence of cementitious materials create an anoxic and alkaline environment. In these conditions, irradiated stainless steel components from NPP slowly corrode, releasing ^{14}C. ^{14}C-bearing molecules are not only markers for RW reaction but they are also important dose-determining ^{14}C carriers that can be released into the atmosphere and into the human food chain. The total ^{14}C inventory of activated steel is well known, while the speciation of released ^{14}C is only poorly known. For that reason the overall purpose of this project is to study the identity of the compounds bearing ^{14}C which are formed during the anoxic corrosion of irradiated steel in alkaline solution.

Systematical radiocarbon dating of Late Neolithic human remains

Inga Siebke

Inga Siebke [1] inga.siebke@irm.unibe.ch
Noah Steuri [2]
Albert Hafner [2]
Sandra Lösch [1]

1. Department of Physical Anthropology, Institute of Forensic Medicine, University of Bern, Switzerland
2. Department of Prehistory, Institute of Archaeological Sciences, University of Bern, Switzerland

Collective burials of the Late Neolithic are found all over Europe; however, undisturbed inhumations are rare. Therefore, the dolmen of Oberbipp in Switzerland, with approximately 40 individuals provides a great opportunity to study the burials. Radiocarbon dating is used in archaeology, nevertheless, often only few samples are analyzed due to funding reasons.

The aim of this project was twofold: a) evaluate the sequence of the burials; b) sample the most frequently occurring bone for dating at least at two laboratories. To achieve this, 1-2g of bone from 31 right *femora* were ^{14}C dated at LARA Bern and CEZ Mannheim.

CEZ obtained data of 29 samples while LARA obtained data of 25 samples, resulting in a minimal sample size of 25. The 2-sigma range of both laboratories are in concordance for 19 samples dating the use of the dolmen from 3400 to 3000 BCE but do not indicate a specific burial sequence until now. 16% (n=4) of the data ranges do not overlap with a discrepancy of 178 to 334 years, while 20% (n=5) show a complete overlap. Based on those results, 11 femora were sampled again and are currently analyzed at RAU Oxford.

The results from CEZ and LARA indicate that the dating of the samples vary little between laboratories, but show a difference in the deviation of the uncalibrated data. Hence, international collaborative ring trails concerning different materials are mandatory. Funding for ^{14}C analyses should be applied for and granted concerning archaeological research routinely.

Establishment of routine sample preparation protocols at the newly installed MICADAS ^{14}C dating facility at AWI

Torben Gentz

Torben Gentz [1] torben.gentz@awi.de
Elizabeth Bonk [1]
Jens Hefter [1]
Hendrik Grotheer [1]
Gesine Mollenhauer [1]

1. Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung

In November 2016, the first Mini-Carbon-Dating-System (MICADAS) manufactured by Ionplus AG was delivered and installed at the Alfred-Wegener-Institute (AWI), Germany. The new facility is additionally equipped with an automated graphitization unit (AGE3) connected with an elemental analyser (EA), an automated carbonate handling system (CHS), and a gas inlet system (GIS) allowing for radiocarbon analyses of CO_2 using the hybrid Cs sputter ion source of the MICADAS instrument.

The main goal for the facility at AWI will be the precise and independent dating of carbonaceous materials in marine sediments, sea-ice, and water. A wide range of in-house research topics address various processes of global carbon cycling. A particular focus will be on sediments from the high latitude oceans, in which radiocarbon-based age models are often difficult to obtain due to the scarcity of carbonate microfossils. One advantage of the MICADAS and its hybrid ion source is the potential to analyse samples, which contain only a small amount of carbon as CO_2 gas. For example, it will be possible to determine ^{14}C ages of samples of foraminifera from carbonate-lean sediments, allowing for paleoclimate reconstructions in key locations for Earth's climate system such as the Southern ocean. Likewise, compound-specific ^{14}C analyses receive growing attention in carbon cycle studies and require handling of small samples of typically less than 100 µg carbon.

The wide range of applications encompassing gas analyses of small-sized samples of foraminifera and compound-specific analysis as well as analyses of graphite targets from samples of ~1µg carbon requires establishing routine protocols of various methods of sample preparation, as well as thorough assessment of the respective carbon blanks. We report on our standard procedures for samples of organic matter from sediments or water including carbonate removal, combustion and graphitization using the AGE3 coupled to the EA, as well as on the methodology applied for carbonate samples using the CHS system and the GIS.

We have investigated different sample preparation protocols and present the initial results using materials of known age. Additionally, we present the first results of our assessment of process blanks at AWI.

Radiocarbon measurements of small-size foraminifer samples with the accelerator mass spectrometer (AMS) MIni-CArbon DAting System (MICADAS) at the University of Bern

Julia Gottschalk

Julia Gottschalk [1] julia.gottschalk@geo.unibe.ch
Sönke Szidat [2] Elisabeth Michel[3] Alain Mazaud [3] Gary Salazar [2] Michael Battaglia [2] Jörg Lippold [1, 4] Samuel L. Jaccard [1]

1. Institute of Geological Sciences and Oeschger Center for Climate Change Research, University of Bern, Bern, Switzerland
2. Department of Chemistry and Biochemistry and Oeschger Centre for Climate Change Research, University of Bern, Bern, Switzerland
3. Laboratoire des Sciences du Climat et de l'Environnement, LSCE/IPSL, CNRS-CEA-UVSQ, Université de Paris-Saclay, Gif-sur-Yvette, France
4. Institute of Earth Sciences, Heidelberg University, Heidelberg, Germany

Radiocarbon (^{14}C) measurements of foraminifera are important to understand past ocean circulation dynamics and the global carbon cycle, and often provide the only absolutely-dated age constraints in marine sediments. Foraminiferal ^{14}C analyses are often challenging as their reliability and accuracy can be compromised by a reduced availability of adequate sample material. Here we use planktonic and benthic foraminifer samples from the South Indian Ocean and from the Ontong-Java-Plateau to test the consistency of ^{14}C ages of large foraminifer samples (>1 mg $CaCO_3$) obtained with conventional accelerator mass spectrometry (AMS) with those of small foraminifer samples (<1 mg $CaCO_3$) obtained with the MIni-CArbon DAting System (MICADAS). We also assess the reproducibility and precision of MICADAS ^{14}C analyses on foraminifera, contamination biases, and foraminifer-specific ^{14}C background concentrations. Our results show that the reproducibility of planktonic and benthic foraminifer gas ^{14}C measurements is respectively 200 ^{14}C yr (n=9) and 110 ^{14}C yr (n=4). The agreement between both carbonate standards and their reference values as well as between small gas- (0.4±0.08 mg $CaCO_3$) and larger (3.2±1.1 mg $CaCO_3$) graphitized foraminifer samples (within 60±20 ^{14}C years, n=7) indicate the high precision of the analyses. We observe a constant contamination bias and slightly higher background ^{14}C levels for foraminifera compared to carbonate reference materials, limiting gas ^{14}C age determinations to foraminifera no older than 43 ^{14}C kyr. Our findings underline the significance of MICADAS gas analyses for ^{14}C on small-size foraminifer samples, in particular when sample size limitations make conventional ^{14}C measurements difficult or impossible.

Design of a new Gas Ion Source interface for biomedical ^{14}C analyses

Daniele De Maria

Daniele De Maria[1] ddemaria@phys.ethz.ch
Simon Fahrni[2]
Lukas Wacker [1]
Hans-Arno Synal [1]

1. Laboratory of Ion Beam Physics, ETH Zurich, Switzerland
2. Ionplus AG, Dietikon, Switzerland

Radiocarbon analyses by accelerator mass spectrometry (AMS) have a great potential for biomedical applications, in particular for metabolism studies using ^{14}C as a microtracer. Since these studies require the measurement of a large number of samples in a short period of time, a key problem of AMS technology is its low sample throughput. Therefore, our aim is to improve the Gas Interface System used for routine gas measurements with the MICADAS at ETH Zurich to achieve a faster measurement process. The current gas handling system is based on a trap containing a molecular sieve material (zeolite X13) from which the gaseous CO_2 is released into a syringe used to regulate the carbon mass flow into the AMS system. In order to avoid cross-contamination between two consecutive samples, an extensive cleaning procedure of the trap and the syringe is required after each sample. To overcome this time consuming process, the new design features two traps working in an alternating way. The gaseous CO_2 released from the traps is flushed directly into the AMS system, skipping the use of the syringe. In order to keep a constant mass flow into the source, the feeding pressure is regulated by a valve system.

^{14}C measurements of biogenic and anthropogenic methane sources

Christophe Espic

Christopher Espic[1] christophe.espic@dcb.unibe.ch
Michael Liechti[1]
Michael Battaglia[1]
Gary Salazar[1]
Sönke Szidat[1]

1. Department of Chemistry and Biochemistry and Oeschger Centre for Climate Change Research, University of Bern, Bern, Switzerland

Methane contributes substantially to global warming as the second most important anthropogenic greenhouse gas. Methane sources are diverse and remain poorly quantified and not well understood. The radiocarbon (^{14}C) content of these emissions is of growing interest since it can be used as a tool for a methane source apportionment (Lassey et al., 2007). Indeed, contemporary methane (e.g. agriculture, biomass burning) contains present-day ^{14}C levels whereas fossil methane (e.g. fossil fuels, geologic sources) is ^{14}C-free. However, this task is challenging given the very large amounts of methane required and its very low concentration in the atmosphere. Methane is usually cryogenically separated from other trace gases (mainly CO and CO_2) but cross contamination remains an issue difficult to overcome (Pack et al., 2015).

Our research aims at enabling the extraction of methane from various kinds of environments (atmosphere, fresh waters and wetlands) and performing ^{14}C measurements with the AMS MICADAS in our laboratory (Szidat et al., 2014). We adapt and develop analytical setups to preconcentrate methane directly in the field in order to bring small samples to the lab where methane is purified and prepared for ^{14}C measurements. We develop a preparative gas chromatography technique to obtain pure methane from the preconcentrated samples and prepare them for ^{14}C analysis with an AMS.

References

Dlugokency et al., *Philos. Trans. R. Soc. London Ser. A*, **369**, 2058 (2011)
Lassey et al., *Atmospheric Chemistry and Physics*, **7**, 2141 (2007)
Pack et al., *Organic Geochemistry*, **78**, 89 (2015)
Szidat et al., *Radiocarbon,* **56**, 561 (2014)

Establishing consistent and accurate chronologies for climate archives with radiocarbon

(Session chair: Julia Gottschalk)

Invited: ^{14}C Reservoir Effects in lakes: implications for ^{14}C dating of sediments and novel opportunities

Martin Grosjean

Martin Grosjean [1] martin.grosjean@oeschger.unibe.ch

1. OCCR, Uni Bern, Switzerland

^{14}C dating is among the most common techniques to assess ages of lake sediments. Typically, lake sediments consist of a myriad of substances with organic and inorganic C from different sources (atmosphere, terrestrial biosphere, geologic bedrock and hydrosphere), different biogeochemical pathways, and different transport and depositional histories. Many of these C-bearing substances in lake sediments have assimilated 'aged' C and, in consequence, show depleted ^{14}C values with respect to atmospheric CO_2 at the time of their formation ($A_0 << 100$ pmC). The resulting difference between the 'apparent' (measured) age and the 'real' age (age of formation) is known as the '^{14}C Reservoir Effect'. Further complications may arise from complex transport histories and multiple deposition-remobilization processes of ^{14}C datable material in lake sediments, which may result in age differences between the 'apparent' age (of the dated material) and the depositional age (the time of final deposition in the sediment stratigraphy).

In my presentation I will briefly review the carbon cycle in lakes and discuss the sources and sinks of ^{14}C datable material in lake sediments with regard to their ^{14}C inventories and potential ^{14}C Reservoir Effects. Examples from different lakes and datable materials will show that Reservoir Effects are highly variable from site to site and also in time. I will briefly discuss how Reservoir Effects can be assessed and corrected for. Whereas ^{14}C may be tricky for age determinations of lake sediments, substance-specific ^{14}C analyses offer novel and yet largely unexplored opportunities for the investigation of past biogeochemical cycling and physical processes in lakes (and oceans).

Keynote: New frontiers in high-precision radiocarbon dating of sediment sequences in palaeoecology

Fabian Rey
Fabian Rey [1, 2] fabian.rey@ips.unibe.ch
Erika Gobet [1, 2]
Sönke Szidat [2, 3]
Adrian Gilli [4]
Albert Hafner [2, 5]
Othmar Wey [2, 5]
Willy Tinner [1, 2]

1. Institute of Plant Sciences, University of Bern, Switzerland
2. Oeschger Centre for Climate Change Research, University of Bern, Switzerland
3. Department of Chemistry and Biochemistry, University of Bern, Switzerland
4. Geological Institute, ETH Zurich, Switzerland
5. Institute of Archaeological Sciences , University of Bern, Switzerland

High-resolution sediment chronologies with best possible time control are essential to compare palaeoecological studies with independent high-precision climatic or societal data (e.g. ice cores, tree rings, stalagmites). We present a novel Neolithic/Early Bronze Age sequence (7000−4000 cal BP) from varved sediments of Moossee and compare the results with the same partly laminated sediment sequence of Burgäschisee. Both chronologies are based on constant year sampling (9−11 years per sample) for radiocarbon dating on terrestrial plant macrofossils and Bayesian models for wiggle matching (OxCal 4.3 program). The results reveal that a careful selection of short-lived, fragile and taxonomically well-defined terrestrial plant remains such as bud scales, leaves, needles, seeds and fruits is essential to reduce radiocarbon dating uncertainties. A comparison with other widely used age-depth modelling approaches such as clam 2.2, generalized mixed-effect regression (GAM) and Bacon 2.2 provides improved results which underline the importance of wiggle-matching to build high-precision sediment chronologies. Here, we can reduce the dating uncertainty from ca. ±50 years for classic varve count chronologies to ca. 20−30 years for combined varve-wiggle matching chronologies. This allows us for the first time to assess linkages between palynologically-inferred high-resolution land-use reconstructions (e.g. crop production, fire) with dendrochronologically dated archaeologically inferred societal dynamics. Similarly, an accurate comparison with highly resolved climate data (e.g. tree-ring records) will now be possible.

Age offsets between climate proxy signals in the Shackleton Sites

Blanca Ausin

Blanca Ausin [1] blanca.ausin@erdw.eth.ch
Magill Clayton [1, 2]
Pascal Wenk [1]
Gerald Haug [1, 3]
Cameron McIntyre [1]
Negar Haghipour [1]
David Hodell [4]
Timothy Eglinton [1]

1. Swiss Federal Institute of Technology Zürich (ETH Zürich), Zürich, Switzerland.
2. Heriot-Watt University, Edinburg, UK
3. Max Planck Institute for Chemistry, Mainz, Germany
4. Cambridge University, Cambridge, UK

Some of the most well-established paleoceanographic proxies (i.e. Total Organic Carbon (TOC), alkenone-derived $U^{k'}_{37}$, and foraminiferal $\delta^{18}O$) are very often applied to sedimentary records and combined as part of a multiproxy approach to constrain past climate variability. Establishing accurate chronostratigraphic records is of particular importance for constraining short-term and abrupt climate changes. Typically, a single age-depth model, often built from radiocarbon ages of planktonic foraminifera, is applied to all proxy records derived from the same core. However, prior studies [e.g. 1,2] show that ^{14}C ages of TOC, alkenones, and foraminifera within the same sediment layer can differ up to several thousand years. These temporal offsets imply proxy signals derived from the same sediment depth interval are asynchronous. Moreover, since this asynchroneity has been related to lateral transport processes, some signals may be non-local in origin.

The so-called "Shackleton sites" on the southwestern Iberian Margin have played a crucial role in the assessment of millennial-timescale climate variability [3]. Here, we attempt to assess temporal relationships among proxies on a sediment core from this benchmark study area. Development of independent, high-resolution ^{14}C chronologies for TOC, planktonic foraminifera, alkenones, and, for the first time, calcareous nannofossils, is ongoing using the Mini-Carbon-Dating-System (MICADAS). Additional down-core ^{14}C analyses performed on the TOC residing in different grain size fractions indicate strong ^{14}C age-grain size dependence for OC, evidencing hydrodynamic control on its provenance and age. Furthermore, magnitude of these temporal offsets over time suggests influence of past climate changes on hydrodynamic forcing conditions.

[1] Ohkouchi *et al*., (2002) *Science*, **298**, 1224-1227.
[2] Mollenhauer *et al*., (2003) *Geochimica et Cosmochimica Acta*, **67**, 2157-2171.
[3] Shackleton *et al*., (2000) *Paleoceanography* **15**, 565-569

Radiocarbon calibration uncertainties during the last deglaciation: Insights from new floating tree-ring chronologies

Florian Adolphi

Florian Adolphi [1, 2] adolphi@unibe.climate.ch
Raimund Muscheler [2]
Michael Friedrich [3, 4]
Dominik Güttler [5]
Lukas Wacker [5]
Sahra Talamo [6]
Bernd Kromer [3]

1. University of Bern, Department for Climate and Environmental Physics
2. Lund University, Deparment for Quaternary Geology
3. University of Heidelberg, Institute of Environmental Physics
4. Hohenheim University, Department of Botany
5. ETH Zurich, Ion Beam Physics
6. Max Planck Institute for Evolutionary Anthropology

Radiocarbon dating is the most commonly used chronological tool in archaeological and environmental sciences dealing with the past 50,000 years, making the radiocarbon calibration curve one of the most important records in paleosciences. For the past 12,560 years, the radiocarbon calibration curve is constrained by high quality tree-ring data. Prior to this, however, its uncertainties increase rapidly due to the absence of suitable tree-ring ^{14}C data. Here, we present new high-resolution ^{14}C measurements from 3 floating tree-ring chronologies from the last deglaciation. By using combined information from the current radiocarbon calibration curve and ice core ^{10}Be records, we are able to absolutely date these chronologies at high confidence. We show that our data imply large ^{14}C-age variations during the Bølling chronozone (Greenland Interstadial 1e) - a period that is currently characterized by a long ^{14}C-age plateau in the most recent IntCal13 calibration record. We demonstrate that this lack of structure in IntCal13 may currently lead to erroneous calibrated ages by up to 500 years.

Radiocarbon analyses of dissolved organic carbon (DOC) in glacier ice

Ling Fang

Ling Fang [1, 2, 3] ling.fang@psi.ch
Johannes Schindler [1, 2, 3]
Theo Jenk [1, 2]
Margit Schwikowski [1, 2, 3]

1. Paul Scherrer Institut, Villigen, Switzerland
2. Oeschger Centre for Climate Change Research, University of Bern, Bern, Switzerland
3. Department of Chemistry and Biochemistry, University of Bern, Bern, Switzerland

The paleoclimatic study of mid-latitudes and tropical mountain glaciers is limited by a lack of dating techniques due to complex bedrock geometry and strong annual layer thinning. Water insoluble organic carbon (WIOC) in glacier ice has been used for radiocarbon dating for years. However, in some cases this method is restricted by the low WIOC concentrations present in the ice. The majority of the carbon containing matter in snow and ice is present as DOC which is therefore the most obvious carbon fraction for dating purposes. Considering the relatively higher concentrations of DOC (50-100 ppb), radiocarbon dating of DOC demand less ice volume and may allow dating even when the WIOC concentration is too low. However, it is highly sensitive to contamination [4] and a study did not succeed in utilizing the DOC fraction for dating probably due to in-situ production in alpine glacier ice.

To investigate the suitability of DO^{14}C dating, we develop an extraction system for ultra-clean and efficient DOC extraction from glacier ice to CO_2. The method, in brief, after cutting and cleaning of ice samples in the cold room at -20^{o}C, samples are melted and further cleaned under helium inert gas conditions in a melting vessel. WIOC is separated by filtration and inorganic carbon (IC) is removed via acidifying and degassing with helium. The remaining DOC in the solution is oxidized by two UV lamps in a quartz glass photo-reactor. Then produced CO_2 is collected by cryogenic traps and further cleaned, quantified and sampled to glass vials for ^{14}C analyses. The Radiocarbon analyses will be conducted at the MICADAS AMS equipped with a gas inlet system of the LARA laboratory, Department of Chemistry and Biochemistry of the University of Bern.

Preliminary results suggest higher oxidation efficiencies for longer irradiation time. The modified extraction setup was designed to monitor the UV oxidation process. Therefore we can adjust the oxidation time based on NDIR CO_2 signal instead of fix the oxidation time. Two critical characteristics, blank and oxidation efficiency, of our setup were investigated. The blank of oxidation process is an average of 0.7± 0.9 µgC, which is determined through fossil standards. The total blank (including ice cutting, filtration and oxidation) is slightly higher than oxidation process. It is about 1.5 ± 0.4 µgC (n=5) using UPW ice. Fe (II) and H_2O_2 at the concentration of 1mM and 100mM were added to accelerate degradation. The full oxidation time needed for Acetate degradation decreased from 70min to within 30min. No additional contamination was observed from Fe (II) and H_2O_2 except a small fraction from added MQ water used to make H_2O_2 dilution. Next, we will focus on the radiocarbon dating of ice core from Piz Zupo to address the seasonal anthropogenic contribution to glacier DOC.

^{14}C age model refinement based on correlated tephra beds at Whitshed lakes, Cordova, Alaska

Paul Zander

Paul Zander [1] paul.zander@students.unibe.ch
Darrell Kaufman [2]
Nicholas McKay [2]
Stephen C. Kuehn [3]
Andrew C. G. Henderson [4]

1. University of Bern, Institute of Geography & Oeschger Centre for Climate Change Research, Switzerland
2. Northern Arizona University, School of Earth Sciences & Environmental Sustainability, United States of America
3. Department of Physical Science, Concord University, Athens, United States of America
4. School of Geography, Politics and Sociology, Newcastle University, Newcastle Upon Tyne, United Kingdom

Stratigraphically correlated, time-synchronous deposits in nearby lakes provide the opportunity to improve age estimates of the sediment sequences, even if the age of the correlated deposit is unknown. We explore this possibility using visible and disseminated tephras in sediment cores from Upper and Lower Whitshed lakes near Cordova, Alaska. The program *Bacon 2.2* in R was used to construct independent age-depth models for the cores based on radiocarbon ages and profiles of short-lived radioisotopes for the surface of the cores. Four Holocene tephra deposits were correlated between the two lakes based on the magnitude and spacing of magnetic susceptibility peaks and glass major-oxide geochemistry. These correlated tephras confirm the age models are in agreement because the independently modeled confidence intervals overlap for each correlated tephra. The correlated tephras were used to improve the age models by extracting the subset of possible age-model ensemble members from the Bacon output that produce similar ages for each of the four correlated tephras at the two lakes. The iterations that agree within 25 years for all four correlated tephra were used to create tephra-matched age models for both lakes, which narrowed the width of the 95% confidence intervals of the age models by roughly 5% overall. Additionally, age estimates for the correlated tephra layers were calculated based on the tephra-matched age model iterations from both lakes. These combined tephra age estimates reduced the uncertainty in age estimates of the correlated tephras by 20-70%. This synchronization technique may be useful in other studies that have multiple independently dated records with confident stratigraphic correlations.

Radiocarbon application for studying paleoclimatic, environmental and anthropogenic changes

(Session chair: Samuel L. Jaccard)

Keynote: Compound-specific radiocarbon dating reveals mobilization of ancient carbon from thawing permafrost

Gesine Mollenhauer

Gesine Mollenhauer [1, 2] gesine.mollenhauer@awi.de
Vera Meyer [1]
Maria Winterfeld [1]
Stephanie Kusch [1, 3]
Janet Rethemeyer [1, 3]
Wolf Dummann [1, 3]
Jens Hefter [1]

1. Alfred Wegener Institute, Helmholtz Centry for Polar and Marine Research, Germany
2. University of Bremen, Germany
3. now at: Cologne University, Germany

Permafrost soils store vast amounts of organic matter. When thawed, this organic matter becomes mobilized and bioavailable, and can be respired to greenhouse gases. Thawing permafrost also leads to massive eriosion of formerly frozen deposits. Some of the eroded material will be re-deposited in marine sediments, leaving records of the thawing history of the hinterland.

Permafrost thawing and the carbon mobilization and respiration resulting from it have been suggested to contribute substantially to the atmospheric greenhouse gas levels by releasing ancient carbon, both during warming events in the past and as a result of anthropogenic climate change in the future. Studies of this process have so far relied on models and only indirect evidence. To date unambiguous direct evidence for large-scale mobilization of ancient permafrost carbon has not been provided.

We used compound-specific radiocarbon analyses of terrigenous biomarkers extracted and purified from marine sediments collected adjacent to areas that are, or have been in the past, underlain be permafrost. We find evidence for increasing accumulation of strongly pre-aged terrigenous organic matter during periods of permafrost thaw or warming. These data sets include records of massive deglacial release of permafrost carbon as well as evidence for recent acceleration of ancient carbon release.

Invited: Radiocarbon dating in archaeology: New examples and case studies from the inner alpine area in Switzerland and Liechtenstein

Mirco Brunner

Mirco Brunner [1, 2, 3] mirco.brunner@iaw.unibe.ch

1. University of Bern, Institute of Archaeological Science, Prehistory Department
2. University of Bern, Oeschger Centre for Climate Change Research, Research Group Prehistory Archeology
3. Graduate School 'Human Development in Landscapes' at Kiel University

The Alps in southern Central Europe act as a barrier and communication space at the same time. While the mountains prevent mobility, the valleys and passes create natural axes for material exchange and communication. The Alpenrhein valley forms the main access to the central Alps and leads directly into the south alpine area between the Lake Maggiore and the Lake Como. In prehistoric times this central axis was used as a settlement area and formed an excellent alpine transit route. Already Neolithic finds show evidence of exchange and communication between inner alpine and pre-alpine regions. From the beginning of the Neolithic to the Bronze Age clear influences from the northern and southern regions are noticeably in favour of trade routes across the alpine passes. Between 3000-2500 BC the region is subject to massive changes which cause a *push effect* towards marginal, less densely populated areas. The broad range of local resources in new territories and strategically well-controlled areas suggest simultaneously a *pull effect* towards the Alps. Therefore Bronze Age is the period for which the most intense prehistoric land expansion can be postulated in the Alps. The Neolithic and Bronze Age chronology for the inner alpine area was always based on comparisons of the material culture from dendrodated lake dwellings from Switzerland or southern Germany. Until a few years ago there existed only a couple of old radiocarbon dates to prove the chronology for the inner alpine area. The archaeology showed its significant influence in the development of the radiocarbon technology in the last decades. New radiocarbon dates from different sites such as graves and settlements give us the opportunity to get a clearer view on the absolute dating of the sites from this area. With the SNF-Project: "Chronology, mobility and cultural transfer. A landscape archaeological study of the central Alps (P0BEP1_165306) " we were able to generate new samples for Radiocarbon dates from Neolithic and Bronze Age Sites such as Lutzengüetle, Savognin, Padnal Donath, Sursés and Laax-Salums. I am going to present an overview of the situation and a revised chronology of the Neolithic and Bronze Age sites from the inner alpine area and recommend a radiocarbon-based view on the development of the material culture.

New approach to radiocarbon dating of paintings

Laura Hendriks

Laura Hendriks [1] laurah@phys.ethz.ch
Irka Hajdas [1] Ester S.B. Ferreira [2] Nadim C. Scherrer [3] Stefan Zumbühl [3] Markus Küffner [4] Caroline Welte [1] Lukas Wacker [1] Hans-Arno Synal [1]
Detlef Günther [5]

1. Laboratory of Ion Beam Physics, ETH Zurich, Switzerland
2. TH Köln, University of Applied Sciences, Germany
3. Bern University of Applied Sciences, BFH/HKB Bern, Switzerland
4. Swiss Institute for Art Research, SIK-ISEA Zurich, Switzerland
5. Laboratory of Inorganic Chemistry, ETH Zurich, Switzerland

In the puzzle of artwork authentication, ^{14}Cdating may play a key role as it can help providing earliest possible dates of when a work of art was created. Despite the achievements already made using ^{14}C analysis in studies of works of art, its application as a routine dating method is still rather limited due to the destructive nature of sample collection. Indeed, tens of milligrams of original material is usually necessary which thus prevents sampling of many valuable objects. This current project aims at the minimization of sample sizes required for ^{14}C dating of paintings. Following successful downscaling of the canvas sample size requirements for Accelerator Mass Spectrometry [1], we further explored the possibility of dating the organic binder in the painting itself.

Radiocarbon analyses were conducted on signed and dated paintings from two Swiss artists of the 20th century. Canvas sample sizes of 200 µg, yielding approximately 20 µg of measurable carbon, were successfully dated using the Gas Ion Source of the MICADAS. Hence, the sample size reduction now offers feasible sampling quantities, which are comparable to those required for GC-MS analysis - a standard analysis technique applied to art objects. Radiocarbon dating of paint binding medium is a more complex subject and in order to obtain valid binding medium ^{14}C measurements, careful and complete material characterization of the selected paint samples is needed. The combination of XRF, FTIR and Raman spectroscopies allows the identification of the paint samples main components including binding medium, pigments and fillers. The selection of paint zones free of carbon sources other than the binder is crucial for the accurate interpretation of the results. Targeted materials are natural binders and specifically drying oils, as they are representative of the time of creation of the object. Ideally, paints made with inorganic pigments are chosen, as they are not primarily carbon based. Resulting ^{14}C ages from the binding medium in two paint samples predate the painting by 4-5 years and correlate with the ^{14}C ages of the canvas. These results illustrate the great potential of dating the binding medium itself and draw its relationship to the age of the support material, hereby offering a new tool in the study of paintings and their origin.

[1] Hendriks et al, **2016**, *Microscale radiocarbon dating of paintings*, Applied Physics A, 122:167.

Estimation of the fossil-fuel component in atmospheric CO_2 based on radiocarbon measurements at the Beromünster tall tower, Switzerland

Tesfaye Berhanu

Tesfaye Berhanu [1] berhanu@climate.unibe.ch Soenke Szidat [2] Dominik Brunner [3] Ece Satar [1] Michael Battaglia [2] Martin Steinbacher [3] Samuel Hammer [4] Markus Leuenberger [1]

1. Climate and Environmental Physics, Physics Institute and Oeschger Centre for Climate Change Research, University of Bern, Bern, Switzerland
2. Department of Chemistry and Biochemistry and Oeschger Center for Climate Change Research, University of Bern, Bern, Switzerland
3. Empa, Laboratory for Air Pollution/Environmental Technology, Dübendorf, Switzerland
4. Institut für Umweltphysik, Universität Heidelberg, Heidelberg, Germany

Fossil fuel CO_2 (CO_{2ff}) is the major contributor of anthropogenic CO_2 in the atmosphere, and accurate quantification is essential to better understand the carbon cycle. Since October 2012, we have been continuously measuring the mixing ratios of CO, CO_2 CH_4 and H_2O at five different heights at the Beromünster tall tower, Switzerland. Air samples for radiocarbon ($\Delta^{14}CO_2$) analysis have also been collected from the highest sampling inlet (212.5 m) of the tower on a bi-weekly basis. A correction was applied for $^{14}CO_2$ emissions from nearby nuclear power plants (NPPs), which have been simulated with the Lagrangian transport model FLEXPART-COSMO. The $^{14}CO_2$ emissions from NPPs offset the depletion in ^{14}C by fossil-fuel emissions resulting in an underestimation of the fossil-fuel component in atmospheric CO_2 by about 16 %. An average observed ratio (R_{CO}) of 13.4 ± 1.3 mmol/mol was calculated from the enhancements in CO mixing ratios relative to the clean air reference site Jungfraujoch (ΔCO) and the radiocarbon-based fossil-fuel CO_2 mole fractions. This ratio is significantly higher than both the mean anthropogenic CO/CO_2 emission ratios estimated for Switzerland from the national inventory (7.8 mmol/mol for 2013), and the ratio between in-situ measured CO and CO_2 enhancements at Beromünster over the Jungfraujoch background (8.3 mmol/mol). Differences could not yet be assigned to specific processes and shortcomings of these two methods but may originate from locally variable emission ratios as well as from non-fossil emissions and biospheric contributions. By combining the ratio derived using the radiocarbon measurements and the in-situ measured CO mixing ratios, a high-resolution time series of CO_{2ff} was calculated exhibiting a clear seasonality driven by seasonal variability in emissions and vertical mixing. By subtracting the fossil-fuel component and the large-scale background, we have determined the regional biospheric CO_2 component that is characterized by seasonal variations ranging between -15 to +30 ppm. A pronounced diurnal variation was observed during summer modulated by biospheric exchange and vertical mixing while no consistent pattern was found during winter.

Deglacial ventilation history of the deep South Indian Ocean: closing important data gaps with ^{14}C analyses of ultra-small foraminifer samples with a Mini CArbon DAting System (MICADAS)

Julia Gottschalk

Julia Gottschalk [1] julia.gottschalk@geo.unibe.ch
Sönke Szidat [2]
Elisabeth Michel [3]
Alain Mazaud [3]
Anja S. Studer [4]
Alfredo Martínez-García [4]
Samuel L. Jaccard [1]

1. Institute of Geological Sciences and Oeschger Center for Climate Change Research, University of Bern, Bern, Switzerland
2. Department of Chemistry and Biochemistry and Oeschger Centre for Climate Change Research, University of Bern, Bern, Switzerland
3. Laboratoire des Sciences du Climat et de l'Environnement, LSCE/IPSL, CNRS-CEA-UVSQ, Université de Paris-Saclay, Gif-sur-Yvette, France
4. Max Planck Institute for Chemistry, Climate Geochemistry Department, Mainz, Germany

The distribution of ^{14}C in the ocean-atmosphere system gives valuable insights into the mechanism that control atmospheric CO_2 ($CO_{2,atm}$) levels and global climate over the last glacial-interglacial transition. Ocean ^{14}C ventilation ages (i.e., deep-ocean to surface or deep-ocean to atmosphere ^{14}C disequilibria) largely reflect the efficiency of air-sea CO_2 exchange, the residence time of carbon and vertical mixing in the ocean. They are also linked with the degree of ocean carbon sequestration. A lack of proxy data from the Indian Ocean hampers gaining a full picture on the magnitude and impact of changes in ocean carbon sequestration on deglacial $CO_{2,atm}$ levels. We present a new suite of paired benthic and planktonic foraminifer ^{14}C ages from the sub-Antarctic Indian Ocean (i.e., sediment core MD12-3396CQ: 47°43.88′S, 86°41.71′E, 3615 m water depth) obtained by ^{14}C analyses (300 to 1,000 µg $CaCO_3$) with the MICADAS at the University of Bern that allow circumventing previous limitations of very low foraminifer abundances in this region. (Sub-)surface ocean temperature estimates allow stratigraphic alignments to Antarctic (ice core) temperature variations, thereby providing independent and robust chronological control. Our new data indicate that glacial deep-ocean ^{14}C (i.e. benthic-atmospheric and benthic-planktonic) ventilation ages were increased compared to mean Holocene levels, although not as strong as for instance observed in the South Atlantic. The transition from a poorly ventilated glacial ocean to a well ventilated Holocene ocean in the sub-Antarctic Indian region parallels similar changes in the South Atlantic. Our findings indicate the importance of ocean dynamics in the Indian Ocean in driving last deglacial $CO_{2,atm}$ changes, and add to the significance of air-sea gas exchange in the Southern Ocean for the global carbon cycle.

Invited: Radiocarbon analysis on carbonaceous particles in ice – method development, ice core dating and source appointed long-term emission records

Theo Jenk

Theo Jenk [1, 2] theo.jenk@psi.ch
Chiara Uglietti [1, 2]
Fang Cao [1, 2, 3]
Johannes Schindler [1, 2]
Ling Fang [1, 2]
Sönke Szidat [2, 4]
Margit Schwikowski [1, 2, 4]

1. Paul Scherrer Institute, Laboratory of Environmental Chemistry, Villigen, Switzerland
2. Oeschger Centre for Climate Change Research, University of Bern, Bern, Switzerland
3. Guangzhou Institute of Geochemistry, Chinese Academy of Sciences, 510640 Guangzhou, China
4. Department of Chemistry and Biochemistry, University of Bern, Bern, Switzerland

The deeper parts of ice cores from cold, high-altitude glaciers and ice caps in mid-latitudes and tropical regions are characterized by strongly thinned annual layers caused by horizontal ice flow induced plastic deformation. To overcome the lack of dating methods for these lowermost sections, a new approach was introduced by our group about 10 years ago. Thereby the µg-amounts of the water-insoluble organic carbon fraction of carbonaceous aerosols (WIOC), continuously embedded in the ice matrix, are extracted and subsequently analysed for dating by ^{14}C. Over the years, this method has constantly been optimized, and by now has become a routinely applied analytical tool of our laboratory.

This talk aims at providing an overview of method development and optimization, revealing insight into some of the analytical quality control key issues such as procedural blanks. Validation of the method dating accuracy will be illustrated based on results from independently dated ice samples taken from a variety of regions. Current limitations and uncertainties will be discussed. By application of this ^{14}C-WIOC dating approach, chronologies could be established for a number of ice cores. This was not only crucial for interpreting the embedded environmental and climatic history, but allowed additional insight into glacier flow dynamics close to the bedrock and the time of glacier formation as will be shown based on selected examples. Radiocarbon analysis of carbonaceous aerosols – dividable into two main contributing fractions (OC and EC) – is not only valuable for dating of ice but also allows constraining contributions from their biogenic and fossil (anthropogenic) emission sources. With respect to air quality, human health and the earth's radiation balance this has become of high interest. However, long-term records are lacking since measurements from ambient samples only cover a few decades and knowledge about pre-industrial atmospheric concentration levels is entirely missing. A first record from the Fiescherhorn ice core (Swiss Alps) covering the time period from 1660 to 2002 will be presented. The talk will concluded with an outlook focusing on our latest efforts for ^{14}C analysis on the dissolved organic carbon fraction of the carbonaceous aerosols (DOC).

^{14}C dating of mortar at the AMS laboratory ETH Zurich

Irka Hajdas

Irka Hajdas [1] hajdas@phys.ethz.ch
Mantana Maurer [1]
Maria Belen Röttig [1]
Jürgen Trumm [2]
Petra Ohnsorg [3, 4]

1. Laboratory of Ion Beam Physics, ETHZ, Switzerland
2. Kantonsarchäologie, Kanton Aargau, Switzerland
3. Amt für Städtebau, Stadtarchäologie Zürich
4. ProSpect GmbH, Aarau, Switzeraland

An interest in direct dating of mortar is growing, as are the chances for cross check of the used preparation methods. Complexity of the mortar requires a holistic approach such as petrographic studies. However, at the moment the method developed and applied in our laboratory is solely based on accuracy of ^{14}C analysis i.e., their agreement with expected/known age of the monuments. The fact that mortars, stucco and fresco i.e., anthropogenic carbonates have different physical and chemical properties is explored in our method. In a process of sieving we separate fine fraction of carbonates (45-63 μm). This fraction is then trapped for AMS analysis after being dissolved in concentrated phosphoric acid. The first 6 sec (2 x 3 sec dissolution interval) are considered to originate from the anthropogenic carbonates. Two more fractions (each 3 sec) are collected to observe the change in ^{14}C ages. In most of the cases the 3rd and 4th fractions are significantly older indicating the presence of old carbonates. We will present and discuss the results obtained on samples collected from Swiss sampling sites with known age as well as ETH results for MODIS inter-comparison project (Hayen et al., 2016).

Hayen R, Van Strydonck M, Boaretto E,' Lindroos A, Heinemeier J, Ringbom Å, Hueglin S, Michalska D, Hajdas I, Marzaoili F, Maspero F, Galli A, Artioli G, Moreau Ch, Guibert P and Caroselli M. 2016. Absolute Dating of Mortars – Integrating chemical and physical techniques to characterize and select the mortar samples. *Proceedings of the 4th Historic Mortars Conference - HMC2016*: 656-667.

Basin-wide compound-specific stable radiocarbon investigation of modern Danube River sediments

Chantal Freymond

Chantal Freymond [1] chantal.freymond@erdw.ethz.ch
Maarten Lupker [1] Nicole Kündig [1] Francien Peterse [1, 2] Björn Buggle [1] Negar Haghipour [1] Cameron McIntyre [3] Florin Filip [4, 5] Liviu Giosan [6] Timothy Eglinton [1]

1. ETH Zürich
2. Utrecht University
3. University of Glasgow
4. University of Bucharest
5. Fabrica de Cercetare, Romania
6. Woods Hole Oceanographic Institution

Rivers are the main driver in the transport of terrestrial organic carbon (OC) from the land to the ocean. Corresponding burial of terrestrial OC in continental shelf sediments comprises an important global carbon sink, and valuable information about past environmental conditions on the continent are stored this sedimentary archive. However, much remains to be understood concerning the provenance and characteristics of terrestrial OC exported by river systems. In this study, we perform a detailed basin-wide investigation of the Danube River, the second largest river in Europe. Fluvial sediments were collected at several locations along the Danube mainstem from the upper reaches to the river mouth, as well as from 12 of its major tributaries. Sedimentological parameters and bulk OC characteristics (%OC, $\delta^{13}C$ and ^{14}C) as well as abundances and isotopic composition ($\delta^{13}C$, ^{14}C, $\delta^{2}H$) of plant wax biomarkers were measured on the sediment fine fraction (<63 μm). Both bulk and fatty acid ^{14}C data reveal a clear trend from young carbon in the upper basin to older carbon (>2000 yr) in the Delta, implying aging during transport and/or addition of pre-aged material in the lower reaches. This aging trend in bulk and compound-specific radiocarbon signatures are accompanied by a substantial overall decrease (70 - 80%) of total OC and biomarker concentrations normalized to mineral surface area from the headwaters to the river terminus. Taken together, these results imply that there is significant transformation of terrestrial OC during transport and that the carbon exported to the Black Sea is probably dominated by a lower basin input.

Constraining the timing of deep-water ventilation changes and the marine reservoir effect in the Southern Ocean between 40-10 kyr BP: A tephrochronological and radiocarbon approach

Peter Abbott

Peter Abbott [1, 2] abbottp@cardiff.ac.uk
Samuel Jaccard [1]
Steve Barker [2]
Julia Gottschalk [1]

1. Institute of Geological Sciences and Oeschger Center for Climate Change Research, University of Bern, Baltzerstrasse 1-3, Bern 3012, Switzerland
2. School of Earth and Ocean Sciences, Cardiff University, Park Place, CF10 3AT, Cardiff, UK

Establishing tighter constraints on phase relationships between sedimentary evidence for deep-water ventilation of carbon dioxide (CO_2), and ice-core evidence for past atmospheric CO_2 variations can help in determining the future response of the Earth system to rising CO_2 levels. The rate and timing of deep-water ventilation can be determined through paired ^{14}C dating of planktonic and benthic foraminifera in marine sequences, however, uncertainty still exists regarding the temporally variable marine reservoir effect, the age offset between the atmosphere and surface waters. Providing independent age control for marine sequences and/or directly synchronising the marine and ice-core records can provide constraints on the reservoir effect and aid comparisons between these records. This can be achieved using tephrochronology, with common horizons of volcanic ash traced between palaeoclimatic sequences acting as time-synchronous tie-lines due to their rapid deposition. This allows ages unaffected by the reservoir effect (e.g. terrestrial ^{14}C, Ar/Ar, ice-core) to be transferred into the marine chronologies.

We are applying this approach within the Atlantic sector of the Southern Ocean, a key area for the release of CO_2 via deep-water ventilation during the deglaciation that has several upwind volcanic systems known to have deposited volcanic ash over the region. Two marine cores with pre-existing ventilation age estimates (MD07-3076Q and TN057-21) are currently under investigation using recently developed methods for the identification of marine cryptotephras, ash horizons not visible upon core inspection. Following their identification attempts will be made to trace them within the Antarctic ice-core records and/or proximal sequences to provide independent age control. Focused ^{14}C dating of planktonic foraminifera around any tephra horizons will help constrain the marine reservoir effect and in addition dating of benthic foraminifera will provide new ventilation age estimates that are independent of reservoir age uncertainties, which have previously complicated ventilation age reconstructions.

Long-term productivity and meromixis dynamics on the Swiss Plateau (Lake Moossee, Switzerland) inferred from Hyperspectral Imaging

Stamatina Makri

Stamatina Makri [1] stamatina.makri@giub.unibe.ch
Martin Grosjean [1]

1. University of Bern Institute of Geography & Oeschger Centre for Climate Change Research

The Anthropocene has seen unprecedented environmental change and fundamental ecosystem services are increasingly at stake. Altered biogeochemical cycles combined with climate change result in global impacts, like increased productivity and anoxia in most freshwater systems (Chapman, 1998; Hecky, 2010). A sound scientific assessment of such changes must rely on on a long-term perspective and high-resolution data. Hyperspectral Imaging (HSI) quantitative proxy records can provide this information (Butz et al, 2015). Mixing regimes are fundamentally important to lake ecology. However, so far information on long-term dynamics of mixing regimes and anoxic events in freshwater lakes is scarce. With this project, we intend to extend applications of the recently developed lake sediments HSI-VNIR methodology by our group, to examine long-term lake productivity and mixing regimes dynamics.

We are currently focusing on the Swiss Plateau (Lake Moossee). We will use imaging spectrometry proxies, quantitative Chl a and chlorins for aquatic productivity and quantitative Bphe a for meromixis (Butz et al, 2016). Bphe a is a bacterial pigment and degradation product of Bacteriochlorophyll a (Bchl a), produced by anoxygenic phototrophic bacteria. Pigment composition and concentrations will be inferred from sets of spectra indices the Relative Absorption Band Depths (RABD). Indices will be calibrated with absolute pigment concentrations of selected samples, measured by HPLC.

The aim is to examine how hypoxia and meromixis developed in small eutrophic lakes in Holocene/Late-glacial time scales, which were the forcing factors and what is the influence of anthropogenic activities in the watershed.

References

Butz C, Grosjean M, Fischer D, Wudnerle S, Tylmann W, Rein B (2015), Hyperspectral imaging spectroscopy: a promising method for the biogeochemical analysis of lake sediments. J Appl Remote Sens 9:096031

Butz C, Grosjean M, Poraj-Górska A, Enters D, Tylmann W. (2016), Sedimentary Bacteriopheophytin a as an indicator of meromixis in varved lake sediments of Lake Jaczno, north-east Poland, AD 1891–2010, Glob. Planet. Change 144: 109–118.

Chapman, L. J., C. a. Chapman, T. L. Crisman, and F. G. Nordlie (1998), Dissolved oxygen and thermal regimes of a Ugandan crater lake, Hydrobiologia, 385, 201–211.

Hecky, R. E., R. Mugidde, P. S. Ramlal, M. R. Talbot, and G. W. Kling (2010), Multiple stressors cause rapid ecosystem change in Lake Victoria, Freshw. Biol., 55, 19–42, doi:10.1111/j.1365-2427.2009.02374.x.

Tsunami deposits in coastal areas surrounding perialpine lakes in Switzerland

Valentin Nigg

Valentin Nigg [1] valentin.nigg@geo.unibe
Stéphanie Girardclos [2]
Katrina Kremer [3]
Flavio Anselmetti [1]

1. Institute of Geological Sciences, University of Bern, Switzerland
2. Department of Earth Sciences and Institute for Environmental Sciences, University of Geneva, Switzerland
3. Swiss Seismological Service, ETH Zurich, Switzerland

On the basis of historical reports, multibeam bathymetric datasets, seismic reflection surveys and numerical wave modelling, previous studies have shown that devastating tsunamis occurred in perialpine lakes in Switzerland. These events have diverse trigger mechanisms such as earthquakes, rockfalls or spontaneous subaquatic mass movements displacing large amounts of water. For instance, a tsunami with a height of 4 m occurred in Lake Lucerne after an earthquake (Mw 5.9) in 1601 AD. (Cysat, 1969; Schnellmann et al., 2002; Fäh et al. 2011; Hilbe and Anselmetti, 2015). At Lake Geneva, a major subaerial rockfall triggered a partial subaquatic collapse of the Rhone delta in 536 AD causing a tsunami with a height of several meters (Montandon, 1925; Kremer et al., 2012).

Based on transect sediment drill cores, this study emphasizes the identification of historic tsunami deposits in coastal settings of Swiss lakes. It will provide the foundation to confirm and quantify historic tsunami events and to extend the event catalogue to the prehistoric period. On the basis of radiocarbon dating, our results will establish a tsunami chronology that will be correlated with major mass-transport deposits observed in the various lake basins (Schnellmann et al., 2002; Kremer et al., 2015). This study is part of an interdisciplinary project, which addresses the causes, controls, frequency of this to date underrated lacustrine tsunami hazard and which also includes numerical modelling of tsunami propagation and inundation. Thus, the information gained from the historic tsunami deposits will serve as groundtruthing the numeric tsunami models developed.

Hyperspectral imaging application to perform high resolution quantitative diagnostic proxy-proxy calibration from varved lake sediments

Andrea Sanchini

Andrea Sanchini [1] andrea.sanchini@giub.unibe.ch
Martin Grosjean [1]

1. Institute of Geography & Oeschger Centre for Climate Change Research Lake Sediments and Paleolimnology Group, University of Bern, Erlachstrasse 9a, 3012 Switzerland

The Anthropocene has seen unprecedented environmental change, and fundamental ecosystem service are increasingly at stake. This is particularly true for climate change and biogeochemical cycles. Interactions of both resulted, for instance, in global spread of anoxia in freshwater systems. However, a sound scientific assessment of such changes must rely on a long term-perspective. Recently, our team have developed novel hyperspectral imaging methods (VNIR-HSI) for the biogeochemical analysis of lake sediments. We have establisched the “proof of concept” that VNIR-HSI data can be used: *(i)* to quantify distribution and time-series of pigments that are diagnostic for aquatic productivity (Chlorophyll a and Chlorins) and meromixis (bacteriopheophytin a) and, *(ii)* to reconstruct annually resolved season-specific quantitative climate variables (ultra-high spatial resolution 45 * 45 μm^2) [1]. So far, we have infered past primary production activity based on the detection and quantification of pigments using hyperspectral analysis and HLPC-DAD/FLD measurement. The reason of our attendance at this workshop is due to the fact that we would like to integrate radiocarbon dating analysis to explore its suitability to perform high resolution quantitative diagnostic proxy-proxy calibration from varved lake sediments. This is important to infer past climate conditions in temperate zones.

[1] Butz, C., Grosjean, M., Fischer, D., Wunderle, S., Tylmann, W., & Rein, B. (2015). Hyperspectral imaging spectroscopy: a promising method for the biogeochemical analysis of lake sediments. Journal of Applied Remote Sensing, 9(1), 096031-096031.

Reconstruction of deep-water circulation in the Indian sector of the Southern Ocean during the Holocene on the basis of ^{14}C measurements of foraminifera

Nicole Schmid

Nicole Schmid [1] nicole.schmid@students.unibe.ch
Julia Gottschalk [1, 2]
Samule L. Jaccard [1, 2]

1. Institute of Geological Sciences, University of Bern
2. Oeschger Center for Climate Change Research

The ocean stores, compared to the terrestrial biosphere, about 60 times more carbon (Sigman and Boyle, 2000). A better knowledge of the processes and timescales of the ocean-circulation is important to make statements about the causes of CO_2-changes in the atmosphere. The goal of this study is to assess the link between deep-water circulation and the rise of CO_2-concentration in the atmosphere during the Holocene (that is unprecedented over past interglacial periods) and to analyse what role the Southern Ocean might play in thisconnection.

Planktic (Globigerina bulloides) and mixed benthic foraminiferas were hand-picked from sediment core MD12-3396Q from the Indian sector of the Southern Ocean (47°44'S, 86°42'E, water depth 3615 m) and dated with the MICADAS (MIni-CArbon-DAting-System) at the University of Bern. Local ventilation ages were estimated on the basis of benthic foraminifera ^{14}C-age deviations from planktonic foraminifera and the contemporaneous atmosphere, and are considered here as a measure of the rate of deep-water circulation at our study site.

To put the results in a bigger context, the data were compared with other radiocarbon-data from the South Pacific, the South Atlantic and South of New-Zealand.

Ventilation age estimates of core MD12-3396Q show a continuous increase until about 5000 years BP. Although CO_2-concentrations in the atmosphere are continuously increasing from 7000 years BP, an invigoration of deep-ocean circulation at our core site can only be observed from 5000 years. BP. Relying on the assumption that a stronger deep-water circulation, particularly in the Southern Ocean, will release more effectively deeply sequestered CO_2 to the atmosphere, we speculate based on our MD12-3396Q data that deep South Indian ocean ventilation contributed to the Holocene increase in atmospheric CO_2 with a time delay an in the Holocene only.

Radiocarbon dating of Bronze Age in Slovakia: status and perspectives

Peter Barta

Peter Barta[1] peter.barta@uniba.sk

1. Department of Archaeology, Faculty of Arts, Comenius University Bratislava, Slovakia

The presentation will summarize ^{14}C chronometry of the Bronze Age in Slovakia, spanning from the Reinecke BA Nitra culture to the Urnfield period of Reinecke HB.

The aim is to present the roots of ^{14}C dating of the Bronze Age in former Czechoslovakia along with current work and prospects in Slovakia. The paper will give a review of chronology and chromology of dated contexts, variety of sample materials and archaeological priors used for Bayesian modeling.

On the backdrop of current research results (APVV-0598-10, APVV-14-0550) needs and foci of future investigations will be shown.

List of Participants

1st Bern Workshop on ^{14}C Analyses with the Mini-Radiocarbon-Dating System (MICADAS)

13 – 15 September 2017, University of Bern, Switzerland

Name	Institution	Address	E-mail
Peter Abbott	University of Bern	Institute for Geological Sciences Baltzerstasse 1+3 3012 Bern Switzerland	peter.abbott@geo.unibe.ch
Florian Adolphi	University of Bern	Climate and Environmental Physics Sidlerstrasse 5 3012 Bern Switzerland	adolphi@climate.unibe.ch
Tabea Arnold	University of Bern	Dept. of Chemistry and Biochemistry Freiestrasse 3 3012 Bern Switzerland	tabea.arnold@students.unibe.ch
Blanca Austin	ETH Zurich	Department of Earth Sciences Sonneggstrasse 5 8092 Zürich Switzerland	blanca.ausin@erdw.ethz.ch

Peter Barta	Comenius University in Bratislava	Department of Archaeology Gondova 2 814 99 Bratislava Slovakia	peter.barta@uniba.sk
Michael Battaglia	University of Bern	Dept. of Chemistry and Biochemistry Freiestrasse 3 3012 Bern Switzerland	michael.battaglia@dcb.unibe.ch
Tesfaye Berhanu	University of Bern	Climate and Environmental Physics Sidlerstrasse 5 3012 Bern Switzerland	berhanu@climate.unibe.ch
Christopher Bronk Ramsey	University of Oxford	School of Archaeology Dyson Perrins Building South Parks Rd Oxford, OX1 3QY United Kingdom	christopher.ramsey@arch.ox.ac.uk
Mirco Brunner	University of Bern	Institute of Archaeological Science Prehistory Department Muesmattstrasse 27 3012 Bern Switzerland	mirco.brunner@iaw.unibe.ch

Giorgia Camperio Ciani	ETH Zurich / EAWAG	Department of Earth Sciences Sonneggstrasse 5 8092 Zürich Switzerland	giorgia.camperio@eawag.ch
Daniele De Maria	ETH Zurich	Laboratory of Ion Beam Physics Otto-Stern-Weg 5 8093 Zürich Switzerland	ddemaria@phys.ethz.ch
Nathalie Dubois	ETH Zurich / EAWAG	Department of Earth Sciences Sonneggstrasse 5 8092 Zürich Switzerland	nathalie.dubois@eawag.ch
Christophe Espic	University of Bern	Dept. of Chemistry and Biochemistry Freiestrasse 3 3012 Bern Switzerland	christophe.espic@dcb.unibe.ch
Simon Fahrni	Ionplus AG	Lerzenstrasse 12 8953 Dietikon Switzerland	fahrni@ionplus.ch
Ling Fang	Paul Scherrer Institute	Analytical Chemistry OFLB/102 5232Villigen PSI Switzerland	ling.fang@psi.ch

Chantal Freymond	ETH Zurich	Department of Earth Sciences Sonneggstrasse 5 8092 Zürich Switzerland	chantal.freymond@erdw.ethz.ch
Torben Gentz	Alfred Wegener Institute	Marine Geochemistry Am Handelshafen 12 27570 Bremen Germany	Torben.Gentz@awi.de
Julia Gottschalk	University of Bern	Institute for Geological Sciences Baltzerstasse 1+3 3012 Bern Switzerland	julia.gottschalk@geo.unibe.ch
Joëlle Graber-Pesonen	University of Bern	Inst. of Archaeological Sciences Near Eastern Archaeology Länggassstrasse 10 3012 Bern Switzerland	joelle.graber-pesonen@iaw.unibe.ch
Martin Grosjean	University of Bern / Oeschger Centre for Climate Change Research	Institute of Geography Paleolimnology Falkenplatz 16 3012 Bern Switzerland	martin.grosjean@oeschger.unibe.ch

Hendrik Grotheer	Alfred Wegener Institute	Marine Geochemistry Am Handelshafen 12 27570 Bremen Germany	hendrik.grotheer@awi.de
Irka Hajdas	ETH Zurich	Laboratory of Ion Beam Physics Otto-Stern-Weg 5 8093 Zürich Switzerland	hajdas@phys.ethz.ch
Laura Hendriks	ETH Zurich	Laboratory of Ion Beam Physics Otto-Stern-Weg 5 8093 Zürich Switzerland	laurah@phys.ethz.ch
Jennifer Herschbach	University of Bern	Institute of Geography Hallerstrasse 12 3012 Bern Switzerland	jennifer.herschbach@giub.unibe.ch
Meret Huwyler	University of Bern	Department of Biology Baltzerstrasse 4 3012 Bern Switzerland	meret.huwiler@students.unibe.ch
Samuel Jaccard	University of Bern	Institute for Geological Sciences Baltzerstasse 1+3 3012 Bern Switzerland	samuel.jaccard@geo.unibe.ch

Theo Jenk	Paul Scherrer Institute	Analytical Chemistry OFLB / 111 5232 Villigen PSI Switzerland	theo.jenk@psi.ch
Ioannis Kouvatsis	University of Bern	Institute for Geological Sciences Baltzerstasse 1+3 3012 Bern Switzerland	ioannis.kouvatsis@students.unibe.ch
Ronald Lloren	ETH Zurich	Department of Earth Sciences Sonneggstrasse 5 8092 Zürich Switzerland	ronald.lloren@erdw.ethz.ch
Stamatina Makri	University of Bern	Institute of Geography Erlachstrasse 9a 3012 Bern Switzerland	stamatina.makri@giub.unibe.ch
Mantana Maurer	ETH Zurich	Laboratory of Ion Beam Physics Otto-Stern-Weg 5 8093 Zürich Switzerland	mantana.maurer@phys.ethz.ch
Gesine Mollenhauer	Alfred Wegener Institute	Marine Chemistry Am Handelshafen 12 27570 Bremerhaven Germany	Gesine.Mollenhauer@awi.de

Valentin Nigg	University of Bern	Institute for Geological Sciences Baltzerstasse 1+3 3012 Bern Switzerland	valentin.nigg@geo.unibe.ch
Asli Oflaz	Kiel University	Graduate School Human Development in Landscapes Leibnizstrasse 3 24118 Kiel Germany	sabireaslioflaz@gmail.com
Dipankar Pathak	University of Bern	Institute for Geological Sciences Baltzerstasse 1+3 3012 Bern Switzerland	dipankar.pathak@geo.unibe.ch
Martin Rauber	University of Bern	Dept. of Chemistry and Biochemistry Freiestrasse 3 3012 Bern Switzerland	martin.rauber@dcb.unibe.ch
Fabian Rey	University of Bern	Institute of Plant Sciences Altenbergrain 21 3013 Bern Switzerland	fabian.rey@ips.unibe.ch
Maria Belen Röttig	ETH Zurich	Laboratory of Ion Beam Physics Otto-Stern-Weg 5 8093 Zürich Switzerland	mariaro@phys.ethz.ch

Gary Salazar	University of Bern	Dept. of Chemistry and Biochemistry Freiestrasse 3 3012 Bern Switzerland	gary.salazar@dcb.unibe.ch
Andrea Sanchini	University of Bern	Institute of Geography Erlachstrasse 9a 3012 Bern Switzerland	andrea.sanchini@giub.unibe.ch
Nicole Schmid	University of Bern	Institute for Geological Sciences Baltzerstasse 1+3 3012 Bern Switzerland	nicole.schmid@students.unibe.ch
Luyao Tu	University of Bern	Institute of Geography Erlachstrasse 9a 3012 Bern Switzerland	kaileetu@gmail.com
Edith Vogel	University of Bern	Dept. of Chemistry and Biochemistry Freiestrasse 3 3012 Bern Switzerland	edith.vogel@dcb.unibe.ch
Matthias Vonwiller	University of Bern	Dept. of Chemistry and Biochemistry Freiestrasse 3 3012 Bern Switzerland	matthias.vonwiller@dcb.unibe.ch

Lukas Wacker	ETH Zurich	Laboratory of Ion Beam Physics Otto-Stern-Weg 5 8093 Zürich Switzerland	wacker@phys.ethz.ch
Christiane Yeman	ETH Zurich	Laboratory of Ion Beam Physics Otto-Stern-Weg 5 8093 Zürich Switzerland	yemanc@phys.ethz.ch
Paul Zander	University of Bern	Institute of Geography Erlachstrasse 9a 3012 Bern Switzerland	paul.zander@students.unibe.ch

1 st Bern Radiocarbon/MICADAS Workshop

(Department of Chemistry and Biochemistry, University of Bern, Freiestrasse 3, 3012 Bern)

Wednesday, 13.09.2017 (Lecture Hall S481)

09:15	Julia Gottschalk (University of Bern)	Welcome & introduction & information
Technical developments and improvements of radiocarbon analyses (Session chair: Sönke Szidat)		
09:30	Lukas Wacker (ETH Zurich)	Keynote: Challenges in Radiocarbon analysis: Small samples and accurate dating
10:30	Gary Salazar (University of Bern)	Invited: Developing AMS hyphenations with analytical instruments for atmospheric aerosol characterization
11:00	Coffee Break	
11:30	Simon Fahrni (Ionplus)	Performance of MICADAS ^{14}C Instruments
11:50	Christiane Yeman (ETH Zurich)	Laser Ablation Interface coupled to AMS for online ^{14}C analysis of carbonates
12:10	Sönke Szidat (University of Bern)	How does ^{14}C behave in nuclear waste repositories?
12:30	Lunch	
Establishing consistent and accurate chronologies for climate archives with radiocarbon (Session chair: Julia Gottschalk)		
13:50	Martin Grosjean (University of Bern)	Invited: ^{14}C Reservoir Effects in lakes: implications for ^{14}C dating of sediments and novel opportunities
14:20	Fabian Rey (University of Bern)	Keynote: New frontiers in high-precision radiocarbon dating of sediment sequences in palaeoecology
15:20	Blanca Ausin (ETH Zurich)	Age offsets between climate proxy signals in the Shackeleton Sites
15:40	Coffee Break	
16:10	Florian Adolphi (University of Bern)	Radiocarbon calibration uncertainties during the last deglaciation: Insights from new floating tree-ring chronologies
16:30	Poster introduction "2-min madness"	
17:00 - 18:30	Poster session with drinks and nibbles	

Thursday, 14.09.2017 (Lecture Hall S481)

Radiocarbon application for studying paleoclimatic /Holocene/anthropogenic changes (Session chair: Samuel Jaccard)		
09:30	Gesine Mollenhauer (AWI Bremerhaven)	Keynote: Compound-specific radiocarbon dating reveals mobilization of ancient carbon from thawing permafrost
10:30	Mirco Brunner (University of Bern)	Invited: Radiocarbon dating in archaeology: New examples and case studies from the inner alpine area in Switzerland and Liechtenstein
11:00	Coffee Break	
11:30	Laura Hendriks (ETH Zurich)	New approach to radiocarbon dating of paintings
11:50	Tesfaye Berhanu (University of Bern)	Estimation of the fossil-fuel component in atmospheric CO_2 based on radiocarbon measurements at the Beromünster tall tower, Switzerland
12:10	Julia Gottschalk (University of Bern)	Deglacial ventilation history of the deep South Indian Ocean: closing important data gaps with ^{14}C analyses of ultra-small foraminifer samples
12:30	Lunch	
13:50	Theo Jenk (PSI)	Invited: Radiocarbon analysis on carbonaceous particles in ice – method development, ice core dating and source appointed long-term emission records
14:20	Irka Hajdas (ETH Zurich)	^{14}C dating of mortar at the AMS laboratory ETH Zurich
14:40	Chantal Freymond (ETH Zurich)	Basin-wide compound-specific stable radiocarbon investigation of modern Danube River sediments
15:00	Coffee Break	
15:20 - 16:20	Discussion round (tbc)	
16:20 - 17:20	Lab tour (two groups)	
18:00 - 20:30	Conference Dinner	

Friday, 15.09.2017 (Computer room N212)

Practical on statistical approaches for ^{14}C-based chronologies (Course leader: Christopher Bronk Ramsey, University of Oxford)		
09:00	Christopher Bronk Ramsey	Introduction to Calibration
09:30	Christopher Bronk Ramsey	Hands-on use of OxCal calibration software (entering data, options, dealing with plots,mapping data etc)
10:00	Christopher Bronk Ramsey	Introduction to Bayesian modelling
10:30	Discussion over coffee break	
11:00	Christopher Bronk Ramsey	Hands-on session on phase, sequence models for archaeology of different kinds - Q/A
11:30	Christopher Bronk Ramsey	Testing models/dealing with outliers and possible problems
12:00	Julia Gottschalk	Reporting of radiocarbon data: terminology and conventions
12:30	Lunch	
13:50	Christopher Bronk Ramsey	Age depth modelling for environmental sequences
14:20	Christopher Bronk Ramsey	Hands-on session on age-depth models
14:50	Christopher Bronk Ramsey	Other dating methods
15:20	Peter Abbott	Concepts of tephrachronology and the use of isochronous markers: Examples from the North Atlantic
15:35	Paul Zander	Dating recent sediments with radionuclides: Examples from Alaska
15:50	Discussion over coffee break	
16:20	Christopher Bronk Ramsey	Integrating with other data (proxy data etc)
16:50	Christopher Bronk Ramsey	Hands on session with INTIMATE tool under development
17:20	Christopher Bronk Ramsey	Continued discussion and working with people's own data

Poster Nr.		*Poster contributions*
Technical developments and improvements of radiocarbon analyses		
1	Inga Siebke (University of Bern)	Systematical radiocarbon dating of Late Neolithic human remains
2	Torben Gentz (AWI Bremerhaven)	Establishment of routine sample preparation protocols at the newly installed MICADAS ^{14}C dating facility at AWI
3	Julia Gottschalk (University of Bern)	Radiocarbon measurements of small-size foraminifer samples with the MICADAS at the University of Bern
4	Daniele De Maria (ETH Zurich)	Design of a new Gas Ion Source interface for biomedical ^{14}C analyses
5	Christophe Espic (University of Bern)	^{14}C measurements of biogenic and anthropogenic methane sources
Establishing consistent and accurate chronologies for climate archives with radiocarbon		
6	Ling Fang (PSI)	Radiocarbon analyses of dissolved organic carbon (DOC) in glacier ice
7	Paul Zander (University of Bern)	^{14}C age model refinement based on correlated tephra beds at Whitshed lakes, Cordova, Alaska
Radiocarbon application for studying paleoclimatic /Holocene/anthropogenic changes		
8	Peter Abbott (University of Bern, Cardiff University)	Constraining the timing of deep-water ventilation changes and the marine reservoir effect in the Southern Ocean between 40-10 kyr BP: A tephrochronological and radiocarbon approach
9	Stamatina Makri (University of Bern)	Long-term productivity and meromixis dynamics on the Swiss Plateau (Lake Moossee, Switzerland) inferred from Hyperspectral Imaging
10	Valentin Nigg (University of Bern)	Tsunami deposits in coastal areas surrounding perialpine lakes in Switzerland
11	Andrea Sanchini (University of Bern)	Hyperspectral imaging application to perform high resolution quantitative diagnostic proxy-proxy calibration from varved lake sediments
12	Nicole Schmid (University of Bern)	Reconstruction of deep-water circulation in the Indian sector of the Southern Ocean during the Holocene on the basis of ^{14}C measurements of foraminifera
13	Peter Barta (Comenius University Bratislava)	Radiocarbon dating of Bronze Age in Slovakia: status and perspectives